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**Research Paper
RM-267**

Twenty-Year Performances of Scotch, European Black (Austrian), Red, and Jack Pines in Eastern Nebraska

David F. Van Haverbeke

Abstract

Sources of Scotch, European black (Austrian), red, and jack pines were identified that produce trees, at age 20, which are well-adapted to eastern Nebraska in terms of survival, height and diameter growth, crown and stem characteristics, cone production, and disease resistance. Age/age correlations indicate that provenances of superior height growth can be identified by age 10.

Acknowledgements

The diversity of tree planting materials under study at this and other locations in the Great Plains was made possible through cooperation with the Regional Tree Improvement Project (NC–99, formerly NC–51) of the North Central States Agricultural Experiment Stations.

Credits are due Jonathan W. Wright, Professor of Forestry, Michigan State University, for initiating these regional studies and providing the planting stock; and to Ralph A. Read, Silviculturist (now retired), USDA Forest Service, and Walter T. Bagley, Associate Professor of Forestry (now retired), University of Nebraska, for planting, maintaining, and evaluating the early performances of these species.

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Management Implications

Conifer trees, because of their year-round effectiveness and beauty, are in demand for many uses throughout the Great Plains, including windbreaks for beautifying landscapes and conserving energy around rural and urban homesites, protecting livestock and crops, preventing soil erosion, screening for privacy, reducing noise, and improving wildlife habitat. However, the number of arborescent conifer species native to the Great Plains is limited. Only four species (two pines and two junipers) are indigenous to the central Great Plains.

Evaluation, at age 20, of four introduced pine species (Scotch, European black, red, and jack) provides evidence that certain geographic seed sources of these species produce trees that are well-adapted to eastern Nebraska, and probably to the east-central Great Plains. Selecting and propagating these adapted sources by age 10 can add variety and flexibility to management programs by providing improved trees for Great Plains plantings in the shortest possible time.

Introduction

Twenty-year performances of Scotch (*Pinus sylvestris* L.), European black (Austrian) (*P. nigra* Arnold), red (*P. resinosa* Ait.), and jack pine (*P. banksiana* Lamb.) provenances are evaluated in this paper. Tests of these species were established in the early to mid–1960s as part of a larger cooperative regional tree improvement project (NC–99) of the North Central States Agricultural Experiment Stations (Canavera and Wright 1973; Wheeler et al. 1976; Wright et al. 1966, 1972).

Performances of these four species in the Nebraska plantings of the regional tests were reported previously (Read 1971, 1976; Sprackling and Read 1975a, 1975b). The objective was to test seed sources (provenances) of these introduced species for their adaptability to the central Great Plains environment.

Scotch Pine (*Pinus sylvestris* L.)

Scotch pine has the widest natural distribution of any pine species, occurring throughout Europe and Asia from Spain and Scotland eastward to the Pacific Coast of the USSR and Manchuria, and from north of the Arctic Circle in Norway and Sweden southward to Turkey and Greece (Critchfield and Little 1966) (fig. 1). Many varieties have evolved within the species (Ruby and Wright 1976), attributable to the selective pressures of the many differing environments within the species range.

Figure 1.—Natural distribution of Scotch pine (*Pinus sylvestris* L.) and locations of provenances tested in eastern Nebraska (Read 1971).

Scotch pine has been widely planted in the United States for more than 200 years, and is adaptable to a broad spectrum of site conditions. In the past, it was planted mainly in the eastern United States, with only limited use in the eastern Great Plains as a landscape and windbreak tree. However, during the past several decades, it has become an important exotic in the United States because of its greatly increased use for Christmas trees.

The brown spot needle blight fungus (*Scirrhia acicola*) inflicts severe damage to southern European sources in North Central region Christmas tree plantations (Skilling and Nicholls 1974); it also is present in this and in other Great Plains plantings. However, its impact in the Great Plains has been negligible.

European Black (Austrian) Pine (*Pinus nigra* Arnold)

The dark green foliage, distinctive form, and adaptability of European black pine to a wide range of soil types has made it one of the most popular and commonly planted exotic species in the United States since Colonial times (Wright and Bull 1962). This taxon is hardy in southern New England, the North Central states, and in parts of the West. Its resistance to damage from the tip moth insect *Rhyacionia bushnelli* Busck, was largely responsible for its success in the Nebraska, Kansas, and Oklahoma shelterbelts planted during the Prairie States Forestry Project of the Dust Bowl era (Read 1958).

The discontinuous natural range of European black pine extends from eastern Spain, Morocco, and Algeria in western Europe to southern and eastern Turkey; and in the north from Austria and Yugoslavia to the Crimea, USSR (Critchfield and Little 1966) (fig. 2).

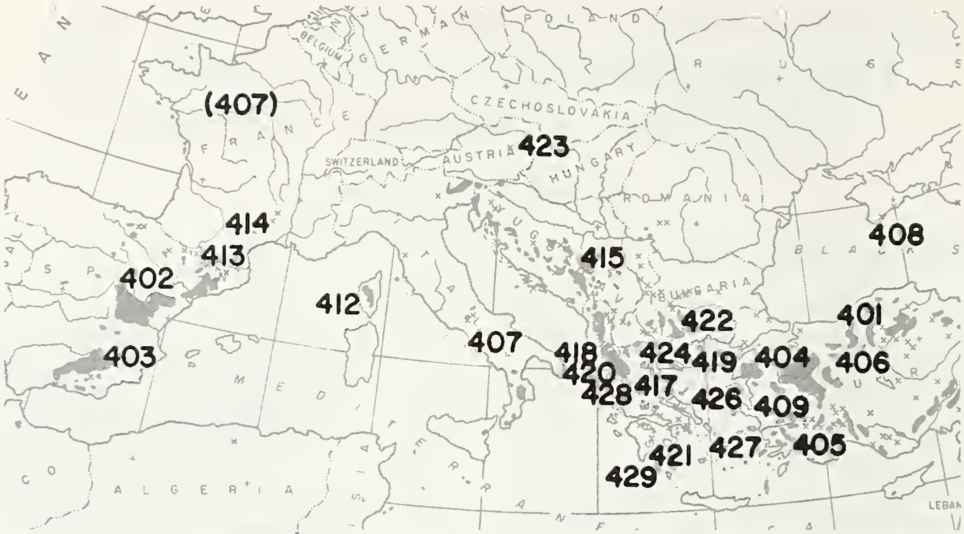

Figure 2.—Natural distribution of European black (Austrian) pine (*Pinus nigra* Arnold) and locations of provenances tested in eastern Nebraska (Read 1976).

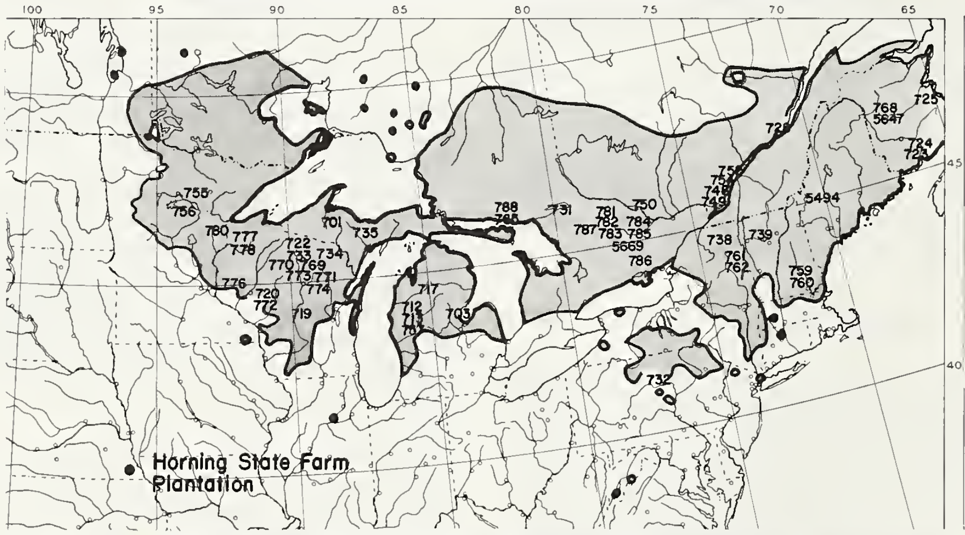

Figure 3.—Natural distribution of red pine (*Pinus resinosa* Ait.) and locations of provenances tested in eastern Nebraska (Sprackling and Read 1975a).

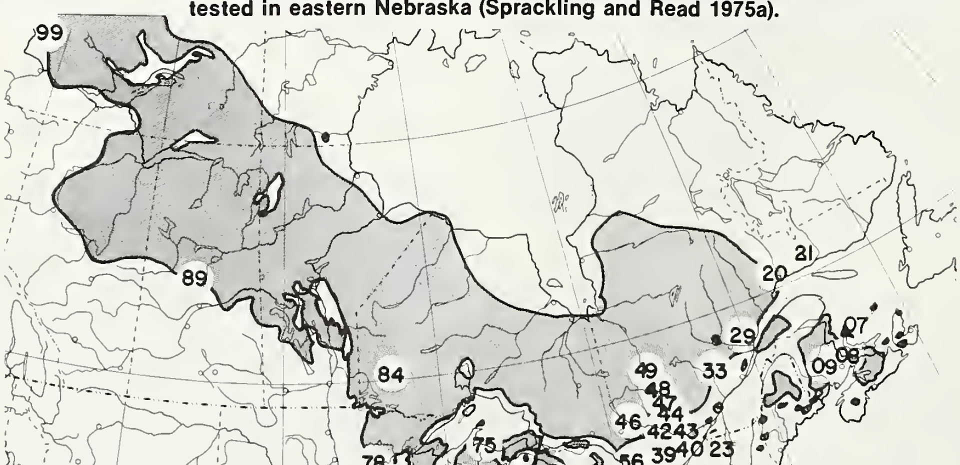

Figure 4.—Natural distribution of jack pine (*Pinus banksiana* Lamb.) and locations of provenances tested in eastern Nebraska (Sprackling and Read 1975b).

European black pine is susceptible to attack by the tip blight fungus, *Diplodia pinea*, and the needle blight fungus, *Dothistroma pini* (Peterson 1973, 1977). Both diseases can be fatal to European black pine under favorable conditions, but are controllable with proper applications of the fungicide Bordeaux mixture (Peterson 1981).

Red Pine (*Pinus resinosa* Ait.)

Native to the boreal forests of North America, red pine has not been planted extensively in the Great Plains. Specifically, the natural range of this species extends from Nova Scotia westward across southern Quebec to southwestern Manitoba, and southward to northwestern Minnesota, Wisconsin, central Michigan, New York, and central Pennsylvania (Little 1971, 1979) (fig. 3). Outliers occur in Newfoundland, West Virginia, and northern Illinois.

Red pine, also referred to as Norway pine, is considered to be an old species, with relatively little genetic variation (Fowler and Lester 1970). Similarity of the present species with a 100-million-year-old Cretaceous fossil species found in Minnesota suggests an ancient heritage (Chaney 1954).

Identification of those seed sources that are best adapted to the Great Plains environment would add to the number of available species available for landscapes, windbreaks, Christmas trees, and other uses within the region (Sprackling and Read 1975a).

Jack Pine (*Pinus banksiana* Lamb.)

Jack pine was planted in the central Great Plains as early as 1891 (Pool 1953). In the early 1900s, tens of thousands of wild seedlings were transplanted from native forests in Minnesota and Wisconsin into the Sandhills of central Nebraska along the Middle Loup River, to establish the Nebraska Forest Reserves—now the Nebraska National Forest (Sprackling and Read 1975b). By 1930, 4,600 acres had been planted. However, despite the large area planted and the satisfactory development of much of the stock, it has not been possible to validate the repeatability of its performance, because there was no accurate documentation of seed origin and no statistical design in the plantings.

Jack pine has a very broad native distribution, extending from the Northwest Territories of Canada to New Brunswick and Prince Edward Island; and southward through the Lake States into northern Indiana (Critchfield and Little 1966) (fig. 4).

Neither jack pine nor red pine·has insect or disease problems of consequence in the Great Plains.

Materials and Methods

Seedlings of the four species were grown at the Michigan State University nursery in East Lansing, and were field-planted at the University of Nebraska Horning State Farm, near Plattsmouth, Nebraska (41° N. lat., 96° W. long., elevation 1,100 feet). Mean annual precipitation at the farm is 30 inches, the growing season averages 170 days, and the soils are silt-loams derived from loess.

Randomized complete blocks of 4-tree linear plots were machine-planted on sites prepared by disking the previous fall. Field designs, establishment procedures, and dates of evaluation are outlined in table 1.

Maintenance of all four plantations included chemical control of competing vegetation with simazine (4 lbs active ingredient per acre) sprayed in a 20-inch band on each side of the rows of seedlings at the beginning of the first four growing seasons, or until the seedlings were established. Vegetation between rows was mowed several times each season. Silvical treatments have been applied periodically in the four plantations as outlined in table 2.

Quantitative data were collected conventionally; qualitative data were derived using rating scales defined in footnotes to the appropriate tables. Data were evaluated by standard analysis of variance techniques, and the testing level for rejection of null hypotheses was set at alpha = 0.05. Only class values were recorded for the ordinal variables of infection by *Dothistroma pini*, stem crook, crown density, and cone production in European black and Scotch pine; thus, a nonparametric analogue of analysis of variance (Kruskal-Wallis test) was used to test for significance among provenances. A procedure adapted from Hollander and Wolfe (1973) was used to make comparisons between sources. Because as many as six response variables were utilized in the evaluation of these pine species, cluster multivariate analysis techniques (Ball and Hall 1965, Scott and Knott 1974) also were used as summarization tools to simplify the interpretation of provenance performances. Genetic age/age correlations were computed to determine at what age provenance selections could be made with reliability.

Results and Discussion

Scotch Pine (8-Year Results)

The eighth-year field evaluation of the 36 rangewide provenances (Read 1971) revealed that southern sources from Georgia in the USSR, Turkey, Greece, Yugoslavia, southern France, and Spain grew slowly to moderately fast, averaging 10.5 feet in height (89% of plantation mean), and remained green to blue-green in the winter. They are recommended for Christmas trees. Central European sources from Poland, Germany, Czechoslovakia, Hungary, England, and France grew fast, averaging 13.4 feet in height (114% of plantation mean), turned yellow-green in the winter, and are recommended for general planting and windbreaks. Northern sources from Siberia, Finland, Sweden, Scotland, the Urals of the USSR, and Latvia grew slowly, averaging 9.4 feet in height (79% of plantation mean), turned very yellow in the winter, and are recommended for special purpose ornamentals.

Table 1.—Summary of field designs, establishment procedures, and evaluation dates for Scotch, European black, red, and jack pine provenance tests in eastern Nebraska.

Variables	Species			
	Scotch pine	European black pine	Red pine	Jack pine
Number of sources	36	25	54	28
Number of replications	7	5	8	6
Plots	4 tree linear			
Date planted	1962	1962	1963	1965
Class of seedlings	2+1	2+1	1+0	3+0
Spacing	7 × 14 ft	7 × 14 ft	6 × 12 ft	5 × 10 ft
1st evaluation	8-yr.,1971	12-yr.,1976	11-yr.,1973	9-yr.,1973
2nd evaluation	20-yr.,1981	20-yr.,1981	20-yr.,1982	20-yr.,1984

Table 2.—Plantation maintenance treatments applied to the Scotch, European black, red, and jack pine provenance plantations.

	Pruned[1]	Thinned[2]	Sprayed[3]	Other[4]
Scotch	1974	1970–76		
European black	1972		1970	
Red	1975			1968
Jack	1979			

[1]*Lateral branches removed up to 6 feet.*
[2]*Plantation thinned as crowns closed and to release selected phenotypes.*
[3]*Bordeaux mixture applied to control Dothistroma needle blight.*
[4]*Removed 43% of trees killed by wildfire.*

A source of Turkish origin (collected near provenance 220 in western Turkey) is now being grown at the USDA Forest Service Bessey Nursery for general distribution in the Clarke-McNary Tree Distribution Program.

Scotch Pine (20-Year Results)

Trees in the central European provenances still were superior in height growth to trees in the southern and northern European provenances, with 17 of the 23 significantly tallest provenances being from central Europe (table 3). Heights of central European provenances averaged 35.6 feet and ranged from 32.9 to 38.4 feet. Trees in southern and northern provenances averaged 31.6 feet in height and ranged from 27.2 to 34.9 feet (table 3). Provenance mean heights reported at age 8 (Read 1971) correlated strongly with mean heights at age 20 ($r = 0.96$).

Trees in the southern and northern European provenances had significantly straighter stems; 15 of 18 provenances with the least amount of stem crook were of southern or northern origin. In contrast, 15 of 18 provenances with the most stem crook were of central European origin. Stem crook was negatively correlated ($r = -0.79$) with height (i.e., tall trees tended to have the most stem crook) (table 4). Most of the entries in the upper rankings of provenances for denseness of crown were from central European provenances; but denseness of crown was not highly correlated with other criteria (table 4). There was no apparent difference in the denseness of crowns between trees in the southern and northern European provenances.

Trees from the central European provenances produced the most cones; 15 of the top 18 cone producing provenances were from central Europe (table 3); and cone production was strongly correlated ($r = 0.7$) with height, diameter, stem crook, and crown density (table 4). Trees from northern European provenances produced the fewest cones. The highest cone rating (3.4) for a central European provenance was more than five times that of the lowest cone rating (0.6) for a northern provenance (table 3). These results are in accord with data reported at age 8 (Read 1971).

ISODATA cluster analysis, using normalized data, separated the provenances into three groups (clusters): cluster No. 3 includes provenances in which the trees are taller, larger in diameter, denser of crown, higher in cone production, but with more stem crook than trees in provenances of cluster No. 1 (table 3). Cluster No. 2 is comprised of provenances whose trees are slower growing and less productive.

Winter Injury

The ability of an introduced species to tolerate the extremes of the environment at the new site is vital to its survival. The Scotch pine provenance plantation is at the eastern edge of the Great Plains region. While it is one

Table 3.—Mean height, diameter, stem crook, crown density, and cone production of 20-year old Scotch pine provenance trees in Nebraska.

Provenance Origin	No.	Region[1]	Height	Prov. ID	Region	Diameter	Prov. ID	Region	Stem crook[2]	Prov. ID	Region	Crown density[2]	Prov. ID	Region	Cone prod.[2]
			(ft.)			(in.)			(no.)			(no.)			(no.)
GRE	272(2)[3]	S	27.2 a[4]	256	N	5.3 a[4]	530	C	1.2 a[5]	272	S	1.4 a[5]	256	S	0.6 a[5]
FRA	240(2)	S	27.9	230	N	5.4	250	C	1.4	245	S	1.5	272	N	0.6 b
FIN	230(2)	N	28.0	260	N	6.1 b	237	C	1.4	260	N	1.7	260	N	0.9 c
SIB	256(2)	N	28.1	522	N	6.1	318	C	1.5 b	218	S	1.7 b	230	N	1.5 d
SWE	522(2)	N	28.8 b	272	S	6.4 c	241	C	1.6 c	553	C	1.8	257	N	1.6 e
SPA	245(2)	S	29.4 c	240	S	6.6 a	307	C	1.7 d	240	S	1.8	245	S	1.6 f
SPA	218(2)	S	29.9 a	257	N	6.8 e	204	C	1.8 e	256	N	1.8	522	N	1.7
URA	257(2)	N	32.1 d	223	N	6.9 f	306	C	1.8	203	C	1.8	223	N	1.8 g
URA	260(2)	N	32.3	265	N	6.9 a	553	C	1.9 f	317	C	2.0	264	S	1.9
SCO	265(1)	N	32.5	239	S	7.2 bg	270	C	1.9 g	223	N	2.0	218	S	1.9
FRA	239(1)	S	32.6 be	553	C	7.8 h	556	C	2.1 h	257	N	2.0	551	S	2.0
ITA	557(1)	C	32.9 f	261	S	7.8	239	S	2.1	270	C	2.1	527	C	2.2
GEO	261(1)	S	32.9 c	218	S	7.9	527	C	2.2	204	C	2.1	317	C	2.2
ITA	554(1)	C	34.0 g	551	S	8.0	554	C	2.2	318	C	2.1	261	S	2.2
TUR	220(1)	S	34.2	203	C	8.0	305	C	2.2	230	N	2.1	240	S	2.2
YUG	242(1)	S	34.4	242	S	8.0	317	C	2.3	243	S	2.1	242	S	2.3
GEO	264(1)	S	34.5	264	S	8.1	243	S	2.4	242	S	2.1	553	C	2.3
LAT	223(1)	N	34.5	317	C	8.1	261	S	2.5	551	S	2.1	220	S	2.3 a
GRE	243(1)	S	34.8	318	C	8.2 c	557	C	2.6	527	C	2.1	557	C	2.4 b
CZE	306(3)	C	34.9	527	C	8.2 d	235	C	2.6	220	S	2.1	265	N	2.5
GRE	551(1)	S	34.9	554	C	8.3	223	N	2.6	264	S	2.1	243	S	2.5
ITA	556(3)	C	35.0	243	S	8.3	257	N	2.7	235	C	2.2	235	C	2.5
GER	204(3)	C	35.4	245	S	8.4	551	S	2.8 a	261	S	2.2	307	C	2.5
ENG	270(3)	C	36.0	305	C	8.4	203	C	2.9	557	C	2.2	554	C	2.6
GER	203(1)	C	36.1	270	C	8.5	260	N	2.9	522	N	2.2	237	C	2.6
BEL	318(3)	C	36.3 d	557	C	8.5 e	522	N	3.0 b	305	C	2.2	203	C	2.6 c
GER	527(1)	C	36.4	204	C	8.5 f	220	S	3.0	237	C	2.2	305	C	2.7
FRA	235(1)	C	36.6	307	C	8.6	265	N	3.1 c	265	N	2.2	239	S	2.8
HUN	553(1)	C	36.6 e	235	C	8.6	264	S	3.1	554	C	2.2	306	C	2.9
CZE	305(3)	C	36.7	306	C	8.8	218	S	3.1	250	C	2.2	241	C	3.0
POL	317(1)	C	36.9	530	C	8.8	240	S	3.2 d	530	C	2.2	204	C	3.0
GER	250(3)	C	37.2 f	241	C	8.9	230	N	3.2	239	S	2.3	556	C	3.2
CZE	307(3)	C	37.2	220	S	9.0	256	N	3.2 e	241	C	2.4 a	318	C	3.2 d
BEL	530(3)	C	37.4	237	C	9.0 g	245	S	3.3 f	307	C	2.4	530	C	3.2 e
FRA	241(3)	C	37.6	250	C	9.2	272	S	3.3 g	306	C	2.5	270	C	3.3 f
FRA	237(3)	C	38.4 g	556	C	9.3 h	242	S	3.4 h	556	C	2.8 b	250	C	3.4 g

[1]*C = Central European*
N = Northern European
S = Southern European
[2]*0 = crooked stem, sparse crown, few cones*
4 = straight stem, dense crown, many cones
[3]*ISODATA, cluster analysis: provenances with same number( ) performed similarly.*
[4]*Tukey's multiple range test: means within the same letter bracket do not differ at the 5% level of probability.*
[5]*Kruskal-Wallis multiple range test: means within the same letter bracket do not differ at the 5% level of probability.*

of the most favorable environments in the Great Plains for tree growth, it also is one of the least selective for determining adaptability for the entire Great Plains region. Trees in all of the provenances, while performing differently because of adaptive differentiation, have not been stressed to the limits of their environmental tolerances by variables such as drought and winter injury.

During 1971–74, a clonal seed orchard was established with ramets derived from ortets selected in the Scotch pine provenance plantation. This orchard was established on an upland and more exposed site 35 miles west of the provenance plantation (Van Haverbeke 1974, 1981a, 1981b). In the winter of 1976–77 (Van Haverbeke 1979), and again in 1983–84, ramets in this orchard suffered varying amounts of foliage burn (table 5). In 1976–77, ramets in the northern European clones 265 (Scotland), 318 (Belgium), 527 (Germany), and the southern European clone 218 (Spain) incurred some winter injury.

The total amount of foliage burn was much greater in the winter of 1983–84 than in the winter of 1976–77, and occurred primarily in the southern European clones 218 and 245 from Spain and 239 and 240 from France (table 5). Foliage burn varied among clones within provenances from severe burning over the entire crown (H–218–1, Spain) to very slight needle tip burn (K–239–1, France) (table 5).

Table 4.—Correlations between tree growth traits in 20-year-old Scotch pine provenances.

	Tree height	Stem diameter	Stem crook	Crown density	Cone prod.
Tree height	-	0.770[1]	-0.786	0.426	0.695
Stem diameter		-	-0.624	0.558	0.744
Stem crook			-	-0.575	-0.785
Crown density				-	0.642
Cone production					-

[1]*Correlations involving ordinal variables were estimated using Spearman's rank correlation coefficient; coefficients are significant at the 5% level of probability.*

Table 5.—Multiple range test for winter injury rating of Scotch pine seed orchard clones.

Source (Clone)	Origin	Number of cases per clone[1]	Mean winter injury rating[2]
H-218-1	SPA	19	3.632 g[3]
J-245-1	SPA	20	2.900 fg
K-245-2	SPA	19	2.579 efg
I-240-1	FRA	20	2.400 efg
N-245-3	SPA	19	2.316 efg
L-218-3	SPA	20	1.950 efg
F-245-1	SPA	20	1.550 defg
J-245-1	SPA	21	1.524 defg
G-245-1	SPA	21	1.333 cdefg
K-239-1	FRA	20	1.300 bcdefg
N-240-4	FRA	17	0.941 abcdef
G-265-2	SCO	20	0.700 abcde
I-240-4	FRA	24	0.667 abcde
B-220-3	TUR	20	0.350 abcd
D-318-3	BEL	20	0.250 abc
B-551-3	GRE	20	0.200 abc
L-242-1	YUG	20	0.200 abc
G-557-1	ITA	21	0.143 abc
G-243-4	GRE	20	0.200 abc
L-261-3	GEO	21	0.190 abc
F-554-4	ITA	17	0.118 abc
B-554-4	ITA	19	0.105 ab
M-557-2	ITA	20	0.100 ab
N-264-2	GEO	20	0.100 ab
G-242-3	YUG	20	0.100 ab
A-240-4	FRA	20	0.100 ab
L-527-4	GER	21	0.095 ab
B-527-3	GER	15	0.133 a
I-243-1	GRE	17	0.118 a
G-242-1	YUG	19	0.053 a
G-556-1	ITA	20	0.050 a
J-264-1	GEO	20	0.050 a
E-239-2	FRA	20	0.050 a
F-264-1	GEO	21	0.048 a
E-261-3	GEO	21	0.048 a
M-220-4	TUR	21	0.048 a
H-551-3	GRE	25	0.0 a
I-203-2	GER	21	0.0 a
K-203-2	GER	20	0.0 a
M-551-2	GRE	19	0.0 a
D-235-4	FRA	17	0.0 a

[1]*Basis: 20 ramets per clone*
[2]*0 = no injury*
1 = trace of injury to a few needles of a few shoots
2 = slight injury to all needles on several shoots
3 = moderate injury to all needles on many shoots
4 = severe injury, most of crown affected
[3]*Hollander and Wolf's (1973) multiple range test: means within the same letter bracket do not differ at the 5% level of probability.*

Injury to clones from the northern European provenances 265, 318, and 527, also occurred in 1983–84 but was much less severe than in 1976–77. Differing combinations and intensities of climatic stress (drought, wind, temperature) are probable causes for differences between the two evaluations (Eiche 1966).

Despite the severity of foliage burn in some clones during the winter of 1983–84, no ramets were killed; and evidence of injury was virtually undetectable by the following summer. Foliage burn detracts from the value of Scotch pine trees intended for sale as Christmas trees; but unless severe, it is not of particular concern for windbreak use because the injury, if slight, is not fatal.

These results suggest that, because of natural selection, certain clones within southern European provenances (218, 240, and 245) lack genes which confer a high degree of winter hardiness in this Nebraska seed orchard environment. Therefore, it is important to know as much as possible about the environments of the provenance origins and the environments of the intended planting sites prior to seed orchard establishment.

European Black Pine (12-Year Results)

Analysis of trees from 25 provenances, at age 12 in the field, showed significant differences among provenances in height, rate of growth, flowering, cone production, needle dimensions, and resistance to *Dothistroma pini.* Source 415, from Yugoslavia, was the fastest growing and was highly resistant to *Dothistroma* pini; it was recommended for planting in eastern Nebraska (Peterson and Read 1971, Read 1976). Height growth and resistance to the needle blight fungus were not correlated, because trees in provenances 418, 420, and 428 from Greece, and 423 from Austria, with a range of heights from tall to short, also showed resistance. Most origins were moderately to highly susceptible. Southern provenances from Spain and Corsica generally grew slowly because of winter injury and susceptibility to *D. pini.*

A seedling orchard was established in 1975, at the University of Nebraska Field Laboratory near Mead, Nebr. (41°10′N lat., 96°25′W long., elevation 1,160 ft.), with selections from the Dothistroma needle blight resistant Yugoslavian seed source 415.

European Black Pine (20-Year Results)

Significant differences among the 22 surviving provenances were demonstrated by analysis of variance for tree height, stem diameter, stem crook, cone production, and incidence of Dothistroma needle blight (table 6). Application of Tukey's multiple range test produced a characteristic result; that is, provenances with extreme values were significantly different, but provenances expressing intermediate values were associated within a multilayered series of overlapping groups.

ISODATA cluster analysis identified four groups of provenances (clusters) of differing performance (table 6). Of importance is the isolation of provenance 407 (ITA) from the other faster growing provenances of cluster No. 1 (table 6), based apparently on higher cone production but with higher disease susceptibility. Also, provenances 412 (COR) and 403 (SPA) are identified as the worst of the slow growing provenances.

Interpretation of simple correlations between mean provenance traits shows that tall trees generally have greater stem diameters, more stem crook, denser crowns, less cone production, and less needle blight (table 7).

Although correlations between mean provenance trait values and the geographical variables of latitude, longitude, and elevation were not statistically significant, the data appear to contain some pattern. Trees in the central to eastern portions of the species distribution (Austria, Yugoslavia, Turkey, USSR) tend to be taller, have larger stem diameters, denser crowns, and less needle blight. A negative correlation between incidence of needle blight and longitude indicates greater susceptibility to needle blight in the southerly Corsican and Spanish provenances. The Yugoslavian provenance 415, reported by Peterson and Read (1971) as highly resistant to Dothistroma needle blight, continues to have one of the lowest numerical disease susceptibility ratings and is among the tallest provenances (table 6). Other provenances showing significantly lower infection in this 20-year evaluation. included the Greek provenances 417, 422, and 424. Stem crook appears to be influenced somewhat more by elevation, where one might expect environmental variables as snow and ice to adversely influence tree form; cone production tends to increase as latitude increases.

The low and insignificant correlations between most evaluation criteria and the geographical variables of latitude, longitude, and elevation reflect the discontinuous nature of the species distribution. The discontinuity of the species range suggests the presence of many and varied environmental regimes throughout its distribution. As a result of differing environmental pressures, populations of differing genetic makeup often evolve.

Red Pine (11-Year Results)

Fifty-four rangewide sources of red pine were evaluated in the field at age 11 (Sprackling and Read 1975a). Forty-three percent of the trees in the plantation were destroyed by fire in 1968, at age 5. Of the remaining 57%, 50% of these were affected somewhat by the fire. The burned trees were omitted from this analysis.

Significant differences were reported among provenances, but none among the tallest 27; and no differences in tree form, needle length, or foliage color. There was no correlation between height growth and latitude, longitude, or elevation. A fast-growing source (752) from St. Philomene, Quebec was recommended for windbreak and landscape plantings in eastern Nebraska. Red pine is not currently being grown for general distribution in the Great Plains.

Red Pine (20-Year Results)

The burned, but still living, trees were included in this analysis to quantify any ill-effects on tree development.

Table 6.—Mean height, diameter, stem crook, crown density, cone production, and disease ratings of 20-year-old European black pine provenances in eastern Nebraska.

Provenance ID		Height	d.b.h.	Stem crook[1]	Crown density[1]	Cone prod.[1]	Diseases[2]
Country	No.	(ft.)	(in.)	(no.)	(no.)	(no.)	(no.)
GRE	424(2)[3]	22.1 a[4]	7.8 abc[4]	2.6 a[5]	2.6 bc[5]	1.6 ab[5]	0.9 a[5]
COR	412(4)	24.3 b	5.4 a	2.8 ab	1.2 ab	2.3 ab	3.2 f
SPA	403(4)	25.8	6.7 ab	3.2 abc	1.2 a	0.5 a	3.0 ef
GRE	421(2)	25.9 a	7.6 abc	2.7 abc	2.1 abc	1.3 ab	2.6 def
SPA	402(2)	28.2 c	7.5 abc	2.4 a	1.9 abc	1.8 ab	2.9 def
GRE	426(2)	28.8	8.5 bc	2.6 a	1.5 abc	1.1 a	1.7 abcde
TUR	405(2)	29.3	9.1 bc	2.4 a	1.8 abc	1.4 ab	2.4 cdef
TUR	401(1)	30.2	9.3 c	2.8 ab	2.5 abc	1.5 ab	1.3 abc
SSR	408(1)	30.4	8.5 bc	3.1 abc	1.8 abc	1.0 a	1.1 ab
AUS	423(1)	30.6	8.5 bc	3.1 abc	2.4 abc	2.0 ab	1.0 ab
GRE	422(1)	30.7 b	7.3 abc	4.0 c	2.7 c	1.3 ab	0.8 a
TUR	406(1)	30.7	7.6 abc	2.9 abc	2.1 abc	1.2 a	1.3 abc
GRE	428(1)	31.1	8.2 bc	3.1 abc	1.9 abc	1.4 ab	1.8 abcdef
GRE	419(1)	31.1	8.4 bc	2.8 ab	1.9 abc	1.0 a	1.8 abcdef
TUR	404(1)	31.4	9.1 bc	3.0 abc	1.7 abc	0.8 a	1.3 abc
GRE	420(1)	31.5	8.7 bc	3.9 bc	2.7 bc	0.9 a	1.0 a
TUR	409(1)	31.6	9.0 bc	3.0 abc	2.1 abc	1.3 ab	1.0 ab
ITA	407(3)	31.6	8.8 bc	2.8 ab	1.9 abc	3.6 b	2.2 bcdef
YUG	415(1)	31.8	8.9 bc	3.1 abc	2.8 c	1.1 a	0.8 a
GRE	417(1)	32.0	9.1 bc	3.4 abc	2.5 abc	1.2 a	0.9 a
GRE	418(1)	32.5	9.1 bc	3.3 abc	2.5 bc	2.1 ab	1.2 abc
GRE	427(1)	32.6 c	9.1 bc	3.5 abc	2.2 abc	0.4 a	1.6 abcd

[1] *0 = crooked stem, sparse crown, few cones; 4 = straight stem, dense crown, many cones*
[2] *0 = none, 1 = light, 2 = moderate, and 3 = heavy infection; 4 = tree dead*
[3] *ISODATA, cluster analysis: provenances with same number (in parentheses) performed similarly.*
[4] *Tukey's multiple range test: means within the same letter bracket do not differ at the 5% level of probability.*
[5] *Kruskal-Wallis multiple range test: means within the same letter bracket do not differ at the 5% level of probability.*

Table 7.—Correlations between physiological and pathological characteristics of European black pine.

	Tree height	Stem diameter	Stem crook	Crown density	Cone prod.	Disease incidence
Tree height	-	0.707[1]	0.608	0.424	-0.223*	-0.446
Stem diameter		-	0.145*	0.266*	-0.106*	-0.329*
Stem crook			-	0.428	-0.395*	-0.508
Crown density				-	0.080*	-0.776
Cone production					-	0.131*
Disease incidence						-

[1] *Correlations involving ordinal variables were estimated using Spearman's rank correlation coefficient; asterisked coefficients are not significant at 0.05.*

However, analysis of the data by two-factor analysis of variance was precluded because of the presence of interaction between the burn factor and provenance.

To determine the effect of the burn, a t-test comparing heights of burned and unburned trees was computed for each provenance. Bonferroni's inequality was used to maintain alpha = 0.05 for the set of 49 tests, thus requiring an individual test to be significant at alpha = 0.001 (Miller 1981).

Because of interaction between burning and provenances, separate analyses of the burned and unburned trees were made to assess differences among prove-

nances. In each instance, analysis of variance indicated the presence of significant differences among provenances. However, the large number of provenances precluded use of the usual multiple range test to assess the joint significance of pairwise differences among provenances because of its conservatism in declaring individual differences. Instead, a cluster analysis technique (Scott and Knott 1974) was used to partition the provenances into internally homogeneous groups relative to the differences among groups (table 8).

These results closely approximate those of the 11-year analysis; provenance 752 from St. Philomene, Quebec, although not significantly different from most other provenances, maintained the number 1 ranking in height growth among the unburned provenances (table 8). Of the 20 tallest provenances in this analysis, 17 appeared among the 27 significantly tallest and similar provenances in the 11-year analysis (Sprackling and Read 1975a). Provenances 735 (Mich.) and 772 (Wisc.), which ranked second and third, respectively, in the 11-year analysis, were ranked 6th and 17th, respectively, in this analysis.

The effect of the fire was evident 15 years later; unburned trees averaged 1.8 feet taller than burned trees (table 8). In addition, 19 of 49 provenances exhibited a significant difference between burned and unburned trees; heights of unburned trees exceeded heights of burned trees in 18 out of 19 instances (asterisked in table 8). Trees in provenance 757 (Mich.) were the only exception.

Jack Pine (9-Year Results)

Twenty-eight seed origins were evaluated in the field at age 9 (Sprackling and Read 1975b). Sources from the northwestern part of the natural range, northern Quebec, New Brunswick, and Prince Edward Island grew slower, had poorer form, shorter needles, turned yellower in winter, and produced fewer cones than southern origins. Fast-growing southern origins developed dense, compact, well-shaped crowns because of the multi-nodal growth characteristic of jack pine. A seed source (44) from Petawawa, Ontario, that produced fast-growing trees of good form, was recommended for plantings in Nebraska and is presently being distributed.

Jack Pine (20-Year Results)

Significant differences among provenances were shown by analysis of variance. As in the 9-year evaluation, provenances from northern origins across the species range from the Northwest Territories in Canada (99) to Prince Edward Island (7) were shorter in height than provenances of southern origin in Michigan (74, 71, 75), Wisconsin (69, 67), Minnesota (78), Ontario (46, 56, 43, 39, 84), Quebec (42, 47), and New York (23) (table 10). Height growth was negatively correlated with latitude ($r = -0.62$) but, as expected, was highly correlated with diameter growth ($r = 0.93$). Survival was very high, averaging 97% over all provenances (table 9).

The cluster multiple comparison test (Scott and Knott 1974) partitioned the 28 provenances into four performance groups; provenance 46 from Petawawa Plains, Ontario, while not the single tallest provenance as in the 9-year evaluation, remained in the significantly tallest group of provenances in this evaluation.

Age/Age Correlations

Matrices of genetic correlations (r) for the four pine species were computed on the basis of individual tree heights (table 10). As frequently shown, correlation coefficients decreased with increasing time between measurements (Clausen 1982, Lambeth 1980, Lambeth et al. 1983, Namkoong et al. 1972, Namkoong and Conkle 1976, Squillace and Gansel 1974, Van Haverbeke 1986). The rate of decrease was most rapid in the early years (up to age 8 or 9) of provenance development, with no major changes in curve form thereafter.

Lester and Barr (1966) stated that the choice of an early age at which to estimate performance at a later age appeared to be largely a matter of choosing an acceptable level of r. Assuming a level of about $r = 0.75$ or greater is acceptable, these data indicate ages 6, 11, 11, and 9 would seem to be appropriate for selecting provenances of superior performance in Scotch, European black, red, and jack pines, respectively. These ages generally agree with reports by Lambeth (1980), Lambeth et al. (1983), Nanson (1967), Squillace and Gansel (1974), Van Haverbeke (1983, 1986), and others that the most efficient age for selection is between 5 and 10 years for many conifers.

Conclusions

The 20-year analyses of these four provenance tests indicate there are seed sources of Scotch, European black, red, and jack pine that are well-adapted to the eastern Nebraska environment for height growth, survival, disease resistance, and other characteristics. These evaluations generally confirm that performance trends revealed in earlier evaluations of these provenances are continuing.

Scotch Pine

Central European (Germany, Belgium, France, Czechoslovakia, Hungary, Poland) sources of Scotch pine continue to grow fastest. Also, they have the largest stem diameters, somewhat more crooked stems, the most cones, and the densest crowns. Northern and southern sources continue to grow slowest; and some southern sources from Spain (218, 245) and France (240) are subject to severe winter injury.

These 20-year data indicate that while the Turkish source of Scotch pine (220) shows superiority in diameter growth and desirable foliage color, it is intermediate in height growth and crown density—two important windbreak characteristics. To gain improvement in height growth, stem diameter, and crown density for wind-

Table 8.—Mean heights of red pine provenances containing trees of which part were injured by fire at age 5.

Unburned			Burned		
Origin	Provenance No.	Height	Origin	Provenance No.	Height
		(ft.)			*(ft.)*
QUE	752 *	33.4 a[1]	MIC	712	32.3 a[1]
ONT	731	33.3 a	ONT	781	31.6 a
ONT	765 *	33.3 a	MIC	757 *	31.5 a
NY	762 *	33.1 a	ONT	731	31.3 a
MIC	712	33.0 a	WIS	773 *	31.3 a
MIC	735 *	33.0 a	WIS	778	31.1 a
ONT	781	33.0 a	MIC	713	31.1 a
ONT	783	32.9 a	NH	759	31.0 a
			NBR	768	31.0 a
WIS	773 *	32.8 a	ONT	782	30.9 a
NH	760 *	32.8 a			
ONT	785	32.7 a	ONT	783	30.8 a
ONT	750 *	32.7 a	MIC	735*	30.7 a
WIS	770	32.6 a	WIS	774	30.6 a
ONT	5669 *	32.5 a	WIS	720	30.4 a
NY	738	32.5 a	ONT	784	30.3 a
MIC	703 *	32.5 a	ONT	785	30.3 a
			NY	738	30.3 a
WIS	772 *	32.3 a			
QUE	748 *	32.3 a	ONT	787	30.1 a
WIS	777 *	32.1 a	QUE	748 *	30.1 a
VT	739	32.0 a	WIS	719	30.1 a
ONT	788 *	31.8 a	MIN	755	30.1 a
WIS	720	31.8 a	MIC	703 *	30.1 a
NBR	768	31.8 a	WIS	771	30.0 a
ONT	787	31.7 a	MIC	701	30.0 a
MIC	713	31.7 a	ONT	5669 *	30.0 a
WIS	722 *	31.7 a	NH	760 *	30.0 a
MIN	780	31.7 a	VT	739	30.0 a
			NBR	724	29.8 a
WIS	733 *	31.5 a	QUE	752 *	29.8 a
NBR	724	31.5 a	WIS	722 *	29.7 a
NY	761	31.4 a			
WIS	778	31.3 a	QUE	749 *	29.4 b
MAI	5494 *	31.2 a	NY	762 *	29.4 b
QUE	749 *	31.1 a	NY	761	29.3 b
WIS	771	31.1 a	WIS	734	29.3 b
ONT	782	31.1 a	NBR	5647	29.2 b
MIN	755	31.0 a	QUE	728	29.2 b
QUE	754	31.0 a	MIN	780	29.1 b
WIS	776	31.0 a	WIS	733 *	29.1 b
MIC	701	31.0 a			
WIS	734	30.9 a	ONT	750 *	29.0 b
WIS	774	30.8 a	WIS	772 *	28.9 b
WIS	719	30.7 a	WIS	777 *	28.8 b
ONT	784	30.3 a	ONT	765 *	28.8 b
ONT	786	30.3 a	ONT	786	28.7 b
NBR	725	30.3 a	MAI	5494 *	28.7 b
MIN	756	30.1 a			
NBR	5647	30.0 a	WIS	776	28.5 b
			QUE	754	28.4 b
WIS	769 *	29.1 b	WIS	769 *	28.2 b
QUE	728	29.0 b	MIN	756	28.2 b
MIC	717	28.8 b	WIS	770	28.2 b
MIC	757 *	28.4 b	ONT	788 *	28.1 b
NBR	723	28.0 b			
PA	732	27.7 b	NBR	723	27.3 b
NH	759	27.5 b	NBR	725	26.2 b
$\bar{x}$ height		31.5			29.7

**Those provenances in which the difference between burned and unburned provenance mean heights is significant.*

[1]*Means with the same letter desigation do not differ at the 5% level of probability according to cluster analysis technique of Scott and Knott (1974).*

Table 9.—Twenty-year mean heights, diameters, and survival of trees in 28 jack pine provenances tested in eastern Nebraska.

Provenance Origin	No.	Height	d.b.h.	Lat.	Number of trees 1967	1984	Survival
		(ft.)	*(in.)*				*(%)*
SAS	89(1)[1]	22.2 a[2]	3.8	54.2	15	13	87[3]
QUE	21(1)	23.5 b	4.4	49.7	25	25	100
QUE	20(1)	24.4 c	5.0	49.7	20	20	100
NWT	99(1)	25.2 d	5.2	63.2	11	6	55
QUE	29(1)	25.6 a	4.8	47.6	26	26	100
NBR	8(1)	26.0	6.3	46.0	24	24	100
QUE	49(1)	26.2	5.1	47.8	20	20	100
ONT	40(1)	26.3 b	6.0	44.6	15	15	100
PEI	7(2)	27.2 e	5.3	46.6	22	20	91
QUE	33(2)	27.3 f	5.4	47.3	23	22	96
NBR	9(2)	27.3 c	5.6	46.0	22	21	95
QUE	48(2)	27.8 g	5.6	46.8	22	21	95
QUE	47(3)	28.6	6.3	46.4	22	22	100
NY	23(3)	28.7	6.4	44.3	23	23	100
ONT	84(3)	28.7	5.9	49.8	22	22	100
WIS	67(3)	28.9	6.8	44.3	17	17	100
QUE	42(3)	28.9	6.3	45.5	20	19	95
ONT	39(3)	29.0	6.8	44.6	20	20	100
ONT	43(3)	29.2	6.6	45.5	22	22	100
QUE	44(4)	29.6	6.8	45.8	23	23	100
MIC	75(4)	30.0 d	6.7	46.0	20	20	100
MIC	71(4)	30.2	6.9	44.1	17	17	100
MIC	73(4)	30.3	6.7	44.5	21	20	95
ONT	56(4)	30.3 e	6.5	44.5	21	21	100
ONT	46(4)	30.4	6.8	45.8	22	22	100
MIN	78(4)	30.4 f	6.9	46.3	22	21	95
WIS	69(4)	30.5	7.1	44.8	22	22	100
MIC	74(4)	30.8 g	7.4	44.5	21	21	100

[1]*Means with the same number do not differ at the 5% level of probability according to cluster analysis techniques of Scott and Knott (1974).*

[2]*Tukey's multiple range test: means within the same letter bracket do not differ at the 5% level of probability.*

[3]*Survival is based on number of trees present in 1967.*

breaks, efforts should be made to obtain seed from available central European provenance origins such as 530 (Belgium), 250 (Germany), and 235, 237, and 241 (France) (table 3).

As an alternative to seed procurement at the provenance origin, open-pollinated Scotch pine seed could be collected from ramets of central European origin in the Scotch pine clonal seed orchard at the University of Nebraska Field Laboratory at Mead. This would involve such better performing clones as 235 (France), 203 (Germany), 318 (Belgium), 556 (Italy), and 551 and 243 (Greece) (table 3).

European Black Pine

European black pine trees in the central to eastern portions of the species distribution (Austria, Greece, Yugoslavia, Turkey, and Russia) tend to be taller, and have larger stem diameters, denser crowns, and less needle blight.

The Yugoslavian source of European black pine (415) continues to show a high degree of resistance to Dothistroma needle blight and is recommended for continued distribution. Several other provenances, especially from Greece (417, 420, 422, and 424), also show resistance to this fungus disease.

If seed from the Yugoslavian provenance 415 becomes unavailable, seed should be collected from the seedling European black pine orchard at the University of Nebraska Field Laboratory at Mead. These trees are open-pollinated progenies selected from the *Dothistroma pini* resistant Yugoslavian provenance 415.

Red Pine

The deleterious effects of fire upon height growth of red pine were significant 15 years later, with the total height of unburned trees exceeding that of burned trees by nearly 2 feet. The St. Philomene, Quebec source (752) of red pine, although not significantly different from

Table 10.—Age/age correlations (r) for height among provenances of Scotch, European black, red, and jack pines.

a. Scotch Pine

	Age (years in field)									
	4	5	6	7	8	11	15	17	18	20
4	-	***.97***	***.94***	***.90***	***.88***	.83	.71	.69	.68	.65
5		-	***.99***	***.96***	***.94***	***.89***	.78	.77	.75	.72
6			-	***.99***	***.97***	***.92***	***.82***	.80	.79	.75
7				-	***.99***	***.95***	***.86***	***.84***	.83	.79
8					-	***.97***	***.88***	***.87***	***.86***	.82
11						-	***.91***	***.91***	***.89***	***.86***
15							-	***.96***	***.94***	***.92***
17								-	***.98***	***.95***
18									-	***.96***
20										-

b. European Black Pine

	Age (years in field)									
	2	3	4	5	6	7	8	11	17	20
2	-	***.90***	.82	.77	.74	.71	.65	.55	.36	.31
3		-	***.94***	***.91***	***.88***	.84	.76	.65	.44	.39
4			-	***.97***	***.94***	***.90***	.83	.72	.50	.44
5				-	***.98***	***.95***	***.89***	.78	.57	.51
6					-	***.98***	***.93***	.83	.63	.58
7						-	***.98***	***.90***	.69	.64
8							-	***.95***	.76	.71
11								-	***.84***	.79
17									-	***.93***
20										-

c. Red Pine

	Age (years in field)							
	3	4	5	6	7	9	11	20
3	-	***.96***	***.92***	.82	.65	.52	.48	.36
4		-	***.97***	***.88***	.71	.58	.53	.38
5			-	***.91***	***.75***	.63	.58	.42
6				-	***.94***	***.84***	.78	.53
7					-	***.93***	***.88***	.58
9						-	***.96***	.66
11							-	.72
20								-

d. Jack Pine

	Age (years in field)			
	3	9	15	20
3	-	.69	.54	.43
9		-	***.89***	.76
15			-	***.87***
20				-

many other provenances, continued to maintain the number 1 ranking for height growth among the provenances tested, and is recommended for continued distribution. However, for convenience in obtaining seed, efforts should be initiated to secure seed in the United States from such sources as 712 and 735 from Michigan.

Jack Pine

Southern provenances of jack pine from Michigan, Wisconsin, Minnesota, Ontario, Quebec, and New York continued to grow faster than provenances from more northern latitudes. Provenance 44, from Petawawa, Ontario was not the tallest source, as in the 9-year evaluation, but was in the significantly tallest group. Although it is no longer available, it probably will be distributed through the Clarke-McNary Tree Distribution Program as long as present seed supplies last. In the interim, an effort should be made to procure seed from such even better performing domestic seed sources such as 74 (Michigan), 69 (Wisconsin), or 78 (Minnesota). Refer to Sprackling and Read (1975b) for exact provenance locations.

As an alternative to collecting seed at the original provenance locales, this jack pine provenance plantation could be converted to a seed production area by rogu-

ing the poor performing provenances, retaining those listed above from Michigan (74), Wisconsin (69), Minnesota (78), Ontario (46, 56), and Quebec (44), and others of acceptable performance listed in table 9.

Height characteristics of provenances are well expressed in the field by about age 10, indicating that superior performing provenances can be reliably selected about that age or earlier.

The provenances in these tests represent, not a complete, but an adequate sampling of the genetic variability throughout the natural ranges of these species. Initiation of repetitive or additional provenance tests seems counter-productive. Rather, continuing evaluations of the present materials and utilization of the best material within each species, through selection and breeding, seems the most efficient and productive route to further genetic improvement.

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Sources of Scotch, European black (Austrian), red, and jack pines were identified that produce trees, at age 20, which are well-adapted to eastern Nebraska in survival, height and diameter growth, crown and stem characteristics, cone production, and disease resistance. Age/age correlations indicate that provenances of superior height growth can be identified at about age 10.

Keywords: *Pinus sylvestris*, *P. nigra*, *P. resinosa*, *P. banksiana*, provenance, seed source, age/age correlation, winter injury

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U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

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Flagstaff, Arizona
Fort Collins, Colorado*
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Lincoln, Nebraska
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